# PATENT ABSTRACTS OF JAPAN

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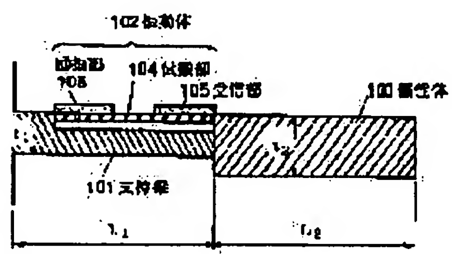
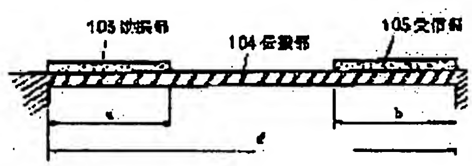
## (54) FORCE SENSOR

(57)Abstract:
PURPOSE: To perform drive in a stable resonant mode by constituting a specific relation between the entire length of a resonator, an excitation piezoelectric element and the length of a receiving piezoelectric element.
CONSTITUTION: A dynamic amount sensor comprises an inertia body 100, a support beam 101, vibrator 102, and piezoelectric elements are provided on the both ends of the vibrator 102, which is constituted of exciting part 103, a propagation part 104 and a receiving part 105. And when acceleration is applied, the inertia body 100 moves up and down, a supporting beam 101 bends and the vibrator 102 expands and contracts. Therefore, when a force is applied, a resonant frequency of the vibrator 102 is changed, and the acceleration can be measured by detecting the frequency change. In addition, the vibrator resonates in various vibration mode. Likelihood of occurrence of the vibration mode is closely related with the length (a) of the exciting part 103, the length (b) of the receiving part 105 and the entire length l of the vibrator 102, and the force sensor can be driven in a stable resonant mode by setting them 0.2≤a/l<0.5, 0.2≤b/l<0.5.




LEGAL STATUS

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CLAIMS

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[Claim(s)]
[Claim 1] The supporting beam which supports a movable inertial field and an inertial field according to an operation of the amount of dynamics, The oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends, The piezoelectric device for excitation which is joined near the end section of said oscillating object, and excites said oscillating object, The piezoelectric device for reception which is joined near the other end of said oscillating object, and receives vibration of said oscillating object is provided. The overall length l of said oscillating object between die-length [ of said piezoelectric device for excitation ] a, and die-length b of said piezoelectric device for reception -- 0.2 <= a/l < -- 0.5 or 0.2 <= b/l < -- Force sensor characterized by there being relation of 0.5.
[Claim 2] The force sensor with which the supporting beam which supports a movable inertial field and an inertial field according to an operation of the amount of dynamics, and the oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends are provided, and primary resonance frequency of said oscillating object is characterized by being 10 or more times of the primary resonance frequency of said inertial field and said supporting beam.
[Claim 3] The supporting beam which supports a movable inertial field and an inertial field according to an operation of the amount of dynamics, The oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends, The piezoelectric device joined on said oscillating object and the electrode of a pair divided in the direction which crosses with the longitudinal direction of said oscillating object on the front face of said piezoelectric device are provided. Another side is the electrode for excitation with which one side of the electrode of said pair excites an oscillating object, and a force sensor characterized by being the electrode for reception which receives vibration of an oscillating object.
[Claim 4] For one side, the electrode of the pair divided and prepared on the piezoelectric device is the force sensor according to claim 3 with which it is the configuration where it is large in the center section of the oscillating object, and narrow near the fixed end, and is characterized by another side being the configuration narrow in the center section of the oscillating object where it is large near the fixed end.

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[Translation done.]

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the sensor which detects the amounts of dynamics, such as acceleration impressed to a body, a load, and a pressure.
[0002]
[Description of the Prior Art] In recent years, development of the air bag system which keeps the insurance in an automobile accident, the navigation system which performs road guidance is prosperous, and the acceleration sensor and a sensor like an oscillating gyroscope are developed in connection with it.
[0003] Conventionally, as a force sensing element, the structure of drawing 9 or drawing 10 is known as shown, for example in JP,53-1330,B. In drawing 9 , make a fixed opening intervene and the piezo-electric diaphragms 2 and 3 of two sheets with which the electrode 1 is attached, respectively are arranged. It is the thing which comes to join this other end together with the spacing plate 5 in rigidity while fixing one edge each of these piezo-electricity diaphragms 2 and 3 to a substrate 4. When Force F is applied to the free end of the piezo-electric diaphragms 2 and 3, the change of each resonant frequency of these piezo-electricity diaphragms 2 and 3 based on the variation rate which the piezo-electric diaphragms 2 and 3 receive at this time is measured, and said force F is measured based on this result. Moreover, when it comes to fix the piezo-electric diaphragms 10 and 11 of two sheets with which a step 7 and a slot 8 are formed in the vertical side of a cantilever 6, a bridge is constructed in a slot 8, and the electrode 9 is attached and Force F is impressed to the free end of a cantilever 6, drawing 10 detects the difference of change of each resonant frequency of the piezo-electric diaphragms 10 and 11, and measures Force F.
[0004]
[Problem(s) to be Solved by the Invention] However, the proper oscillation in the various modes arises in the piezo-electric diaphragms 2, 3, 10, and 11 of the above-mentioned conventional configuration. That is, it was difficult for the normal mode of vibration of the oscillation mode of a lengthwise direction and a longitudinal direction and its high order resonance, and the whole beam, twisting vibration, etc. to exist, and to take out only the normal mode of vibration to use them, carrying out distinction separation clearly [ else ], to be stabilized, and to maintain the resonance state.
[0005] It aims at offering the amount sensor of dynamics to which this invention solves the technical problem of the above-mentioned conventional technique, and the normal mode of vibration of the oscillating object from which a resonant frequency changes can dissociate completely with other unnecessary resonance modes, and can always maintain the fixed resonance state at stability by impression of the force.
[0006]
[Means for Solving the Problem] This invention according to an operation of the amount of dynamics to the 1st in order to attain this purpose A movable inertial field, The supporting beam which supports an inertial field, and the oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends, The piezoelectric device for excitation which is joined near the end section of said oscillating object, and excites said oscillating object, The piezoelectric device for reception which is joined near the other end of said oscillating object, and receives vibration of said oscillating object is provided. The overall length l of said oscillating object between die-length [ of said piezoelectric device for excitation ] a, and die-length b of said piezoelectric device for reception — 0.2 <= a/l < — 0.5 or 0.2 <= b/l < — It is characterized by there being relation of 0.5. Moreover, the oscillating object which was established on the supporting beam which supports a movable inertial field and an inertial field according to an operation of the amount of dynamics, and said supporting beam, and was fixed to the 2nd by said supporting beam in both ends is provided, and primary resonance frequency of said oscillating object is characterized by being 10 or more times of the primary resonance frequency of said inertial field and said supporting beam. The supporting beam which furthermore supports a movable inertial field and an inertial field according to an operation of the amount of dynamics to the 3rd, The oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends, The piezoelectric device joined on said oscillating object and the electrode of a pair divided in the direction which crosses with the longitudinal direction of said oscillating object on the front face of said piezoelectric device are provided. The electrode for excitation with which one side of the electrode of said pair excites an oscillating object, and another side are characterized by being the electrode for reception which receives vibration of an oscillating object.
[0007]
[Function] this invention falls or disappears [ 1st ] the peak of resonance of the higher mode by the above-

mentioned configuration — making — an oscillating object — low — the resonance frequency in degree the mode shows a peak clearly, and the drive of it by the stable resonance mode is attained. Moreover, without the primary resonance frequency of an oscillating object considering as 10 or more times of the primary resonance frequency of an inertial field and a supporting beam, and receiving the effect of the resonance frequency of the whole beam in the 2nd, it can be stabilized and an oscillating object can be resonated. Since the 3rd can be made to produce only the primary resonance frequency of an oscillating object furthermore, the stable drive in primary resonance in the same mode is always possible, and a sensor with little malfunction can be realized.
[0008]
[Example]
(Example 1) The 1st example of this invention is explained hereafter, referring to a drawing.
[0009] Drawing 1 (a) and drawing 1 (b) are the sectional views and top views of the amount sensor of dynamics in one example of this invention. In drawing 1 (a), as for an inertial field and 101, 100 is [ a supporting beam and 102 ] oscillating objects, and said oscillating object 102 consists of the excitation section 103, the propagation section 104, and a receive section 105.
[0010] If acceleration is impressed, an inertial field 100 expands in drawing 1 and contracts the oscillating object 102, while taking up and down and a supporting beam 101 bend. Therefore, when the force acts, the resonance frequency of an oscillating object will change and acceleration can be measured by detecting this frequency change. For example, supposing vibration of an oscillating object can assume that it is vibration of yarn, resonance frequency f is expressed with (several 1).
[0011]
[Equation 1]

$$f = \frac{n}{2l} \cdot \sqrt{\frac{S}{\rho}}$$

[0012] However, in l, the tension of yarn and rho show the mass per unit length of yarn, and, as for the die length of yarn, and S, n shows the degree of vibration. When according to (several 1) resonance frequency f changes in proportion to the square root of the tension of yarn and the force acts, if it is the structure where the tension of an oscillating object changes, it turns out that the amounts of dynamics, such as acceleration, a pressure, and force, can be measured.
[0013] Drawing 2 is an example of a property in the configuration of drawing 1 . An axis of ordinate is the resonance frequency f of an oscillating object, and an axis of abscissa shows the impressed acceleration. According to this, although the resonance frequency at the time of acceleration 0 is 22kHz, when the acceleration of 120G is impressed, it goes up to 27kHz. 1 -- if there is change of about 40Hz per G and it says with rate of change — 0.2%/G — and it could measure to very big acceleration so that it might see in drawing, and the large acceleration sensor of a dynamic range has been realized. In addition, with the structure of drawing 1 , although sensibility changes with ratios of the mass of an inertial field, and the mass of the supporting beam section, in the case of the data of drawing 2 , an inertial field is the thing of the structure of being 7 times much as the supporting beam section, and the deflection of a comparatively minute supporting beam serves as big tension to an oscillating object, acts, and is considered that it was able to output big sensibility.
[0014] One of the structural descriptions of this example is the structure of an oscillating object, and it is a point constituted by the excitation section, the propagation section, and the receive section. Generally, when resonating a piezo-electric ceramic, in the case of the thickness vibration of the piezo-electric ceramic itself etc., there is a method of detecting impedance change of the piezo-electric ceramic itself, and getting to know the resonance point. However, like this invention, when an oscillating object is a zygote of a piezo-electric ceramic and other structural members, it does not restrict that there is a not necessarily big impedance change in the resonance frequency of a zygote, and the resonance point cannot be detected with sufficient sensibility in many cases. Since vibration of the oscillating object which is said zygote is detected by this invention in the direct receive section as compared with it, it becomes possible to detect correctly all vibration that an oscillating object has, and a dimensional degree of freedom will become very big in the design of suitable oscillating object structure.
[0015] Drawing 3 is for explaining the vibrational state of the oscillating object 102 of drawing 1 . Drawing 3 (a) and (b) are the top views and sectional views which carried out expansion illustration of the part of the oscillating object 102. The piezoelectric device is prepared in both ends, the excitation section 103 is constituted by the left end and, as for the oscillating object 102, the receive section 105 is constituted by the right end. Generally, such an oscillating object resonates by the various oscillation modes as shown in drawing 3 (c) - (h), and it is respectively called primary - the 6th resonance mode. With the Young's modulus of the quality of the material which constitutes the thickness of an oscillating object, die length, and an oscillating object etc., the oscillation frequency which such resonance modes produce is determined uniquely, and it does not depend for it on the width of face h of an oscillating object.
[0016] By the stretching vibration of the piezoelectric device of the excitation section 103, when a lifting and the frequency of excitation are in agreement with the frequency of resonance mode to produce in vibration, vibration by resonance mode will produce the oscillating object with which the above ease of occurring of resonance mode has the close relation to die-length a of the excitation section 103. Here, in order to consider die-length a of the excitation section, and the relation of the oscillation mode which is easy to produce, the knot in the 4th resonance mode of drawing 3 (f) and the die length of an internode are set to x as an example. Since the excitation section

deforms by telescopic motion of a piezoelectric device, the natural deformation condition of the excitation section is considered to be the arc shape which uses the both ends of the excitation section 103 as a knot. Therefore, if it is thought that it is easy to produce resonance mode which will be in a and the condition that x is almost equal, for example, x becomes one half extent of a, it will become very difficult for both the extended part and the shrunken part to produce the piezoelectric device of the excitation section, and to produce such the oscillation mode by forced oscillation.

[0017] Although sufficient output signal is acquired in order that similarly it can say the same thing also about die-length b of a receive section 105, and die-length y in drawing 3 (f), and the piezoelectric device of a receive section 104 may receive distortion of the same direction on the whole surface, when it is b**y If y becomes small as compared with b, the part which a reverse distortion produces in the piezoelectric device of a receive section 104 will come be made, in a certain part, by the part of others [ positive charge ], it will be in the condition that negative charge arises, and an output signal will decline again.

[0018] Drawing 4 is an experimental result which shows the frequency characteristics of the output signal outputted from the receive section 105 when changing the dimension of the excitation section 103 and a receive section 105. The axis of abscissa shows the frequency of the input signal of the sinusoidal form impressed to the piezoelectric device of the excitation section 103, and the axis of ordinate shows the output voltage from the piezoelectric device of the receive section at that time. For example, if several V signal level is impressed to the excitation section 103, the output voltage of several mV to hundreds of mV will be obtained from a receive section, but since the value becomes large rapidly with resonance frequency, if a frequency is taken along an axis of abscissa like drawing 4 , the curve which has a peak with resonance frequency will be obtained. Here, the oscillating object 102 pasted up the piezoelectric device (Sumitomo Metal nature H5D) on 4-2 alloy, was produced, and set thickness of 4-2 alloy and a piezoelectric device to 80 micrometers. In drawing 3 , it was referred to as h= 2mm and l= 10mm, and the dimensions a and b of the excitation section 103 and a receive section 105 changed a and b as an equal value.

[0019] Drawing 4 and (a) have a and comparatively large b, although the frequency characteristics at the time of being a/l=0.45 are shown, the peak in the primary resonance mode [ secondary / 3rd ] is seen, and the peak of the 4th resonance [ 5th ] beyond it is not seen. Such high order resonance modes appear as a and b become small, for example, they are produced to the 6th resonance mode in a/l=0.2 like drawing 4 (b). Furthermore, although drawing 4 (c) was the case where a/l=0.15, a, and b were made still smaller, when a and b were too small not much, it turned out that the primary resonance mode [ secondary / 3rd ] of a low degree disappears, and only high order resonance mode appears.

[0020] Generally, it is said that the resonance mode of a low degree is more stable than high order resonance mode. In the case of an oscillating object of a configuration like drawing 3 , this has the crosswise (h) resonance and the resonance mode of twisting vibration other than the oscillation mode shown by drawing 3 (c) - (h). These When it is easy to appear near [ frequency ] high order resonance mode and says with frequency characteristics, the peak in other modes arises near the peak of high order resonance mode, and it is a reason on a circuit that the approach of making it always drive on the frequency of the peak point of high order resonance mode becomes difficult. Therefore, it is good to use the resonance mode of a low degree also in the configuration of this invention, and it is safe to choose any of the primary resonance modes [ secondary / 3rd ] they are. Among these, since this 3rd resonance mode is equivalent to the primary resonance mode of the propagation section 104 when only the propagation section 104 of the oscillating object 102 is observed, the 3rd resonance mode can be considered to be one of the stable basic modes. In using which [ primary / secondary / 3rd ] resonance mode, it turns out from the result of drawing 4 that the structure of filling 0.2 <=a/l<0.5 or 0.2 <=b/l<0.5 is good.

[0021] Next, in order to compare with this example, the force sensor of other structures is explained. Drawing 5 (a) shows other structures of an oscillating object. The piezoelectric device is joined all over the oscillating object, and the electrode on a piezoelectric device 51 is divided into the excitation electrode 52 and the received electrode 53, and the excitation electrode 52 is used for excitation and, as for the difference with drawing 3 , it uses the received electrode 53 for reception. That is, the propagation section 54 of an oscillating object consists of a piezoelectric device 51 and a monotonous zygote, and it is structure without the difference of the excitation section 55, a receive section 56, and thickness. In this structure, when the frequency characteristics of an output signal were measured, it turned out that it becomes like drawing 5 (b), and peak value is low as compared with drawing 3 , many small peaks appear, and it is hard to produce the resonance mode which can be regarded as a clear basic mode. This example this is indicated to be by drawing 3 is assumed to become easy to produce the knot of vibration near the boundary of the excitation section 103, the propagation section 104 or a receive section 105, and the propagation section 104, for example, for peaks, such as the 3rd resonance, to appear greatly when the thickness of the excitation section 103 and a receive section 105, and the propagation section 104 differs.

[0022] In addition, an excitation electrode and a received electrode are replaced, a receive section can get 103 and the effectiveness same naturally also as the excitation section is acquired in 105.

[0023] (Example 2) The 2nd example of this invention is explained hereafter, referring to a drawing.

[0024] Drawing 1 (a) and drawing 1 (b) are the sectional views and top views of the amount sensor of dynamics in one example of this invention. Since it is the same as that of an example 1, explanation of drawing 1 is omitted.

[0025] In drawing 1 , although the oscillating object 102 is installed in the supporting beam 101 which bends with migration of an inertial field 100, resonance mode exists also about the whole beam which consists of an inertial field 100 and a supporting beam 101. Although you may think that this resonance mode is the same as that of outline cantilever vibration, an inertial field often moves by the small force, and although, as for the sensibility as a sensor, the one where the deflection of a supporting beam 101 is larger becomes high, the resonance frequency of the whole

beam falls so much. The resonance frequency of this whole beam is connected with the frequency range of the force impressed to measure. That is, in the case of the acceleration sensor for automobiles, it is necessary to measure correctly the acceleration of the range of 0-500Hz but, and for example, if the resonance frequency of the whole beam exists in this range, it will become difficult to measure the acceleration near [ this ] the resonance frequency correctly. Therefore, although detection sensitivity becomes high so that it is low, more than a frequency range, for example, designed, to measure is desirable [ the resonance frequency of the whole beam ] 500Hz or more so that it may be ideally set to 1kHz.

[0026] Moreover, mutually-independent [ of the resonance frequency of the whole beam and the resonance frequency of the oscillating object 102 ] is carried out, and they must not influence mutually. In order to explain this, the experimental result of drawing 6 is shown. The axis of ordinate shows the output signal electrical potential difference from a receive section 105 for the frequency of the signal with which an axis of abscissa is impressed to the piezoelectric device of the excitation section 103 of the oscillating object 102. The data of drawing 6 are a thing at the time of l= 5mm, a=b=1.5mm, and h= 1mm in drawing 1 in t1=0.4mm, t2=0.8mm, L1=L2=H=5mm, and drawing 3 . In the curve of drawing 6 , fc0, fc1, and fc2 are the peaks of the resonance frequency of the whole beam, and they are respectively equivalent to the primary resonance frequency [ secondary / 3rd ]. Moreover, fs0, fs1, and fs2 are the resonance frequency of the oscillating object 102, and they are equivalent to the primary resonance mode [ secondary / 3rd ] shown in (c) of drawing 3 , (d), and (e). In drawing 6 , fc0, fc1, and fc2 are in fs0 and the distant enough location. That is, the resonance frequency of the whole beam is in the location left with the resonance frequency of the oscillating object 102, and since it does not influence each other, it can be said that it is the structure where a very good result is obtained. However, fc0 When fs0 is a comparatively near frequency, the case where high order resonance frequency (for example, fc4 grade) laps with fs0 arises on the whole beam, and it becomes impossible to detect the resonance frequency of the oscillating object 102 correctly. Considering that high order resonance mode is contained in resonance of the whole beam, the resonance frequency of the oscillating object 102 to be used and the primary resonance frequency of the whole beam can realize a sensor that it is safe that it is separated from single or more figures, and good.

[0027] In addition, an excitation electrode and a received electrode are replaced, a receive section can get 103 and the effectiveness same naturally also as the excitation section is acquired in 105.

[0028] (Example 3) The 3rd example of this invention is explained hereafter, referring to a drawing.

[0029] Drawing 7 and drawing 8 show the structure of the oscillating object of the 3rd example. Although the structure of the oscillating object shown in drawing 3 was structure which high order resonance of the 3rd resonance etc. tends [ comparatively ] to produce, if it may be able to do, structure which only simple primary resonance frequency produces is desired. Drawing 7 and drawing 8 show the oscillating object structure of filling such a demand. In drawing 7 , an inertial field 100 and a supporting beam 101 are constituted like drawing 1 , the plate 106 on a strip of paper is installed in the top face of a supporting beam 101 in the state of both-ends immobilization, and the piezoelectric device 107 is joined by the upper part. When a plate 106 is an insulator, an electrode is prepared between a piezoelectric device 107 and a plate 106, and when a plate 106 is a conductor, fixed potential can be impressed to the inferior surface of tongue of a piezoelectric device by using a plate 106 as an electrode. On the other hand, the excitation electrode 108 and the received electrode 109 with which the top face of a piezoelectric device was divided into right and left to the line which connects the both ends of a plate 106 are prepared.

[0030] Drawing 8 carries out expansion illustration of the part for the oscillating soma of drawing 7 . When the excitation electrode 108 is continuing and excitation voltage is impressed to an excitation electrode from the fixed end of an oscillating object to the fixed end with such structure, it is the easiest to produce the primary resonance mode shown in drawing 8 (C) by expansion and contraction of the whole oscillating object, and stops producing the resonance mode of the gestalt shrunken by elongation and a certain part by forced oscillation in a part with an oscillating object like the secondary resonance [ 3rd ]. That is, about the sensor of drawing 7 , if the same data as drawing 6 are taken, only resonance frequency fs0 will show a peak clearly, and the peak of fs1 and fs2 will be extinguished.

[0031] Drawing 8 (c) shows the primary resonance mode of a both-ends fixed beam. According to this, since both ends are being fixed, it turns out that the direction where a center section bends, and the direction where the part near an edge bends are hard flow. Therefore, since the charge generated in the center section and the charge generated at the end are opposite signs when vibration of primary resonance mode is used, and the received electrode 109 has the same area in every part of a beam, they offset each other, there are and the fault that output voltage declines as a result arises. So, by this invention, as shown in drawing 8 (a), it is large in the center section, and it narrows at the end, the received electrode 109 is large at the edge, and the excitation electrode 108 consists of the reverse narrowly in the center section. Thus, by constituting, the opposite sign component of the charge generated in a received electrode decreases, receiving sensibility rises, it can be sharp and the peak in primary resonance frequency can be made high.

[0032] In addition, an excitation electrode and a received electrode are replaced, a received electrode can obtain 108 and the effectiveness same naturally also as an excitation electrode is acquired in 109.

[0033]

[Effect of the Invention] This invention to the 1st as mentioned above between the overall length l of an oscillating object, die-length [ of said piezoelectric device for excitation ] a, and die-length b of said piezoelectric device for reception 0.2 <= a/l < — 0.5 or 0.2 <= b/l < — By making it the configuration which has the relation of 0.5 the peak of resonance of the higher mode is fallen or disappeared — making — an oscillating object — low — the

outstanding force sensor with which the resonance frequency in degree the mode shows a peak clearly, and the drive of it by the stable resonance mode is attained is realizable.
[0034] Moreover, the outstanding force sensor which it can be stabilized [ force sensor ] and can resonate an oscillating object can be realized by the configuration which the primary resonance frequency of an oscillating object made 10 or more times of the primary resonance frequency of an inertial field and a supporting beam the 2nd, without being influenced of the resonance frequency of the whole beam.
[0035] Furthermore, by the configuration which prepared the electrode of a pair divided towards intersecting the longitudinal direction of an oscillating object on the front face of a piezoelectric device, since only the primary resonance frequency of an oscillating object can be produced, the stable drive in primary resonance in the same mode is always possible, and the outstanding force sensor with little malfunction can be realized [ 3rd ].

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[Translation done.]

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TECHNICAL FIELD

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[Industrial Application] This invention relates to the sensor which detects the amounts of dynamics, such as acceleration impressed to a body, a load, and a pressure.

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[Translation done.]

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PRIOR ART

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[Description of the Prior Art] In recent years, development of the air bag system which keeps the insurance in an automobile accident, the navigation system which performs road guidance is prosperous, and the acceleration sensor and a sensor like an oscillating gyroscope are developed in connection with it.
[0003] Conventionally, as a force sensing element, the structure of drawing 9 or drawing 10 is known as shown, for example in JP,53-1330,B. In drawing 9 , make a fixed opening intervene and the piezo-electric diaphragms 2 and 3 of two sheets with which the electrode 1 is attached, respectively are arranged. It is the thing which comes to join this other end together with the spacing plate 5 in rigidity while fixing one edge each of these piezo-electricity diaphragms 2 and 3 to a substrate 4. When Force F is applied to the free end of the piezo-electric diaphragms 2 and 3, the change of each resonant frequency of these piezo-electricity diaphragms 2 and 3 based on the variation rate which the piezo-electric diaphragms 2 and 3 receive at this time is measured, and said force F is measured based on this result. Moreover, when it comes to fix the piezo-electric diaphragms 10 and 11 of two sheets with which a step 7 and a slot 8 are formed in the vertical side of a cantilever 6, a bridge is constructed in a slot 8, and the electrode 9 is attached and Force F is impressed to the free end of a cantilever 6, drawing 10 detects the difference of change of each resonant frequency of the piezo-electric diaphragms 10 and 11, and measures Force F.

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[Translation done.]

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EFFECT OF THE INVENTION

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[Effect of the Invention] This invention to the 1st as mentioned above between the overall length l of an oscillating object, die-length [ of said piezoelectric device for excitation ] a, and die-length b of said piezoelectric device for reception 0.2 <= a/l < -- 0.5 or 0.2 <= b/l < -- By making it the configuration which has the relation of 0.5 the peak of resonance of the higher mode is fallen or disappeared -- making -- an oscillating object -- low -- the outstanding force sensor with which the resonance frequency in degree the mode shows a peak clearly, and the drive of it by the stable resonance mode is attained is realizable.
[0034] Moreover, the outstanding force sensor which it can be stabilized [ force sensor ] and can resonate an oscillating object can be realized by the configuration which the primary resonance frequency of an oscillating object made 10 or more times of the primary resonance frequency of an inertial field and a supporting beam the 2nd, without being influenced of the resonance frequency of the whole beam.
[0035] Furthermore, by the configuration which prepared the electrode of a pair divided towards intersecting the longitudinal direction of an oscillating object on the front face of a piezoelectric device, since only the primary resonance frequency of an oscillating object can be produced, the stable drive in primary resonance in the same mode is always possible, and the outstanding force sensor with little malfunction can be realized [ 3rd ].

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[Translation done.]

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TECHNICAL PROBLEM

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[Problem(s) to be Solved by the Invention] However, the proper oscillation in the various modes arises in the piezo-electric diaphragms 2, 3, 10, and 11 of the above-mentioned conventional configuration. That is, it was difficult for the normal mode of vibration of the oscillation mode of a lengthwise direction and a longitudinal direction and its high order resonance, and the whole beam, twisting vibration, etc. to exist, and to take out only the normal mode of vibration to use them, carrying out distinction separation clearly [ else ], to be stabilized, and to maintain the resonance state.
[0005] It aims at offering the amount sensor of dynamics to which this invention solves the technical problem of the above-mentioned conventional technique, and the normal mode of vibration of the oscillating object from which a resonant frequency changes can dissociate completely with other unnecessary resonance modes, and can always maintain the fixed resonance state at stability by impression of the force.

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[Translation done.]

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MEANS

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[Means for Solving the Problem] This invention according to an operation of the amount of dynamics to the 1st in order to attain this purpose A movable inertial field, The supporting beam which supports an inertial field, and the oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends, The piezoelectric device for excitation which is joined near the end section of said oscillating object, and excites said oscillating object, The piezoelectric device for reception which is joined near the other end of said oscillating object, and receives vibration of said oscillating object is provided. The overall length l of said oscillating object between die-length [ of said piezoelectric device for excitation ] a, and die-length b of said piezoelectric device for reception -- 0.2 <= a/l < -- 0.5 or 0.2 <= b/l < -- It is characterized by there being relation of 0.5. Moreover, the oscillating object which was established on the supporting beam which supports a movable inertial field and an inertial field according to an operation of the amount of dynamics, and said supporting beam, and was fixed to the 2nd by said supporting beam in both ends is provided, and primary resonance frequency of said oscillating object is characterized by being 10 or more times of the primary resonance frequency of said inertial field and said supporting beam. The supporting beam which furthermore supports a movable inertial field and an inertial field according to an operation of the amount of dynamics to the 3rd, The oscillating object which was established on said supporting beam and fixed to said supporting beam in both ends, The piezoelectric device joined on said oscillating object and the electrode of a pair divided in the direction which crosses with the longitudinal direction of said oscillating object on the front face of said piezoelectric device are provided. The electrode for excitation with which one side of the electrode of said pair excites an oscillating object, and another side are characterized by being the electrode for reception which receives vibration of an oscillating object.
[0007]

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[Translation done.]

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OPERATION

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[Function] this invention falls or disappears [ 1st ] the peak of resonance of the higher mode by the above-mentioned configuration -- making -- an oscillating object -- low -- the resonance frequency in degree the mode shows a peak clearly, and the drive of it by the stable resonance mode is attained. Moreover, without the primary resonance frequency of an oscillating object considering as 10 or more times of the primary resonance frequency of an inertial field and a supporting beam, and receiving the effect of the resonance frequency of the whole beam in the 2nd, it can be stabilized and an oscillating object can be resonated. Since the 3rd can be made to produce only the primary resonance frequency of an oscillating object furthermore, the stable drive in primary resonance in the same mode is always possible, and a sensor with little malfunction can be realized.

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[Translation done.]

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EXAMPLE

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[Example]
(Example 1) The 1st example of this invention is explained hereafter, referring to a drawing.
[0009] Drawing 1 (a) and drawing 1 (b) are the sectional views and top views of the amount sensor of dynamics in one example of this invention. In drawing 1 (a), as for an inertial field and 101, 100 is [ a supporting beam and 102 ] oscillating objects, and said oscillating object 102 consists of the excitation section 103, the propagation section 104, and a receive section 105.
[0010] If acceleration is impressed, an inertial field 100 expands in drawing 1 and contracts the oscillating object 102, while taking up and down and a supporting beam 101 bend. Therefore, when the force acts, the resonance frequency of an oscillating object will change and acceleration can be measured by detecting this frequency change. For example, supposing vibration of an oscillating object can assume that it is vibration of yarn, resonance frequency f is expressed with (several 1).
[0011]
[Equation 1]

$$f = \frac{n}{2l} \cdot \sqrt{\frac{S}{\rho}}$$

[0012] However, in l, the tension of yarn and rho show the mass per unit length of yarn, and, as for the die length of yarn, and S, n shows the degree of vibration. When according to (several 1) resonance frequency f changes in proportion to the square root of the tension of yarn and the force acts, if it is the structure where the tension of an oscillating object changes, it turns out that the amounts of dynamics, such as acceleration, a pressure, and force, can be measured.
[0013] Drawing 2 is an example of a property in the configuration of drawing 1 . An axis of ordinate is the resonance frequency f of an oscillating object, and an axis of abscissa shows the impressed acceleration. According to this, although the resonance frequency at the time of acceleration 0 is 22kHz, when the acceleration of 120G is impressed, it goes up to 27kHz. 1 -- if there is change of about 40Hz per G and it says with rate of change -- 0.2%/G -- and it could measure to very big acceleration so that it might see in drawing, and the large acceleration sensor of a dynamic range has been realized. In addition, with the structure of drawing 1 , although sensibility changes with ratios of the mass of an inertial field, and the mass of the supporting beam section, in the case of the data of drawing 2 , an inertial field is the thing of the structure of being 7 times much as the supporting beam section, and the deflection of a comparatively minute supporting beam serves as big tension to an oscillating object, acts, and is considered that it was able to output big sensibility.
[0014] One of the structural descriptions of this example is the structure of an oscillating object, and it is a point constituted by the excitation section, the propagation section, and the receive section. Generally, when resonating a piezo-electric ceramic, in the case of the thickness vibration of the piezo-electric ceramic itself etc., there is a method of detecting impedance change of the piezo-electric ceramic itself, and getting to know the resonance point. However, like this invention, when an oscillating object is a zygote of a piezo-electric ceramic and other structural members, it does not restrict that there is a not necessarily big impedance change in the resonance frequency of a zygote, and the resonance point cannot be detected with sufficient sensibility in many cases. Since vibration of the oscillating object which is said zygote is detected by this invention in the direct receive section as compared with it, it becomes possible to detect correctly all vibration that an oscillating object has, and a dimensional degree of freedom will become very big in the design of suitable oscillating object structure.
[0015] Drawing 3 is for explaining the vibrational state of the oscillating object 102 of drawing 1 . Drawing 3 (a) and (b) are the top views and sectional views which carried out expansion illustration of the part of the oscillating object 102. The piezoelectric device is prepared in both ends, the excitation section 103 is constituted by the left end and, as for the oscillating object 102, the receive section 105 is constituted by the right end. Generally, such an oscillating object resonates by the various oscillation modes as shown in drawing 3 (c) - (h), and it is respectively called primary - the 6th resonance mode. With the Young's modulus of the quality of the material which constitutes the thickness of an oscillating object, die length, and an oscillating object etc., the oscillation frequency which such resonance modes produce is determined uniquely, and it does not depend for it on the width of face h of an oscillating object.
[0016] By the stretching vibration of the piezoelectric device of the excitation section 103, when a lifting and the frequency of excitation are in agreement with the frequency of resonance mode to produce in vibration, vibration by

resonance mode will produce the oscillating object with which the above ease of occurring of resonance mode has the close relation to die-length a of the excitation section 103. Here, in order to consider die-length a of the excitation section, and the relation of the oscillation mode which is easy to produce, the knot in the 4th resonance mode of drawing 3 (f) and the die length of an internode are set to x as an example. Since the excitation section deforms by telescopic motion of a piezoelectric device, the natural deformation condition of the excitation section is considered to be the arc shape which uses the both ends of the excitation section 103 as a knot. Therefore, if it is thought that it is easy to produce resonance mode which will be in a and the condition that x is almost equal, for example, x becomes one half extent of a, it will become very difficult for both the extended part and the shrunken part to produce the piezoelectric device of the excitation section, and to produce such the oscillation mode by forced oscillation.

[0017] Although sufficient output signal is acquired in order that similarly it can say the same thing also about die-length b of a receive section 105, and die-length y in drawing 3 (f), and the piezoelectric device of a receive section 104 may receive distortion of the same direction on the whole surface, when it is b**y If y becomes small as compared with b, the part which a reverse distortion produces in the piezoelectric device of a receive section 104 will come be made, in a certain part, by the part of others [ positive charge ], it will be in the condition that negative charge arises, and an output signal will decline again.

[0018] Drawing 4 is an experimental result which shows the frequency characteristics of the output signal outputted from the receive section 105 when changing the dimension of the excitation section 103 and a receive section 105. The axis of abscissa shows the frequency of the input signal of the sinusoidal form impressed to the piezoelectric device of the excitation section 103, and the axis of ordinate shows the output voltage from the piezoelectric device of the receive section at that time. For example, if several V signal level is impressed to the excitation section 103, the output voltage of several mV to hundreds of mV will be obtained from a receive section, but since the value becomes large rapidly with resonance frequency, if a frequency is taken along an axis of abscissa like drawing 4 , the curve which has a peak with resonance frequency will be obtained. Here, the oscillating object 102 pasted up the piezoelectric device (Sumitomo Metal nature H5D) on 4-2 alloy, was produced, and set thickness of 4-2 alloy and a piezoelectric device to 80 micrometers. In drawing 3 , it was referred to as h= 2mm and l= 10mm, and the dimensions a and b of the excitation section 103 and a receive section 105 changed a and b as an equal value.

[0019] Drawing 4 and (a) have a and comparatively large b, although the frequency characteristics at the time of being a/l=0.45 are shown, the peak in the primary resonance mode [ secondary / 3rd ] is seen, and the peak of the 4th resonance [ 5th ] beyond it is not seen. Such high order resonance modes appear as a and b become small, for example, they are produced to the 6th resonance mode in a/l=0.2 like drawing 4 (b). Furthermore, although drawing 4 (c) was the case where a/l=0.15, a, and b were made still smaller, when a and b were too small not much, it turned out that the primary resonance mode [ secondary / 3rd ] of a low degree disappears, and only high order resonance mode appears.

[0020] Generally, it is said that the resonance mode of a low degree is more stable than high order resonance mode. In the case of an oscillating object of a configuration like drawing 3 , this has the crosswise (h) resonance and the resonance mode of twisting vibration other than the oscillation mode shown by drawing 3 (c) - (h). These When it is easy to appear near [ frequency ] high order resonance mode and says with frequency characteristics, the peak in other modes arises near the peak of high order resonance mode, and it is a reason on a circuit that the approach of making it always drive on the frequency of the peak point of high order resonance mode becomes difficult. Therefore, it is good to use the resonance mode of a low degree also in the configuration of this invention, and it is safe to choose any of the primary resonance modes [ secondary / 3rd ] they are. Among these, since this 3rd resonance mode is equivalent to the primary resonance mode of the propagation section 104 when only the propagation section 104 of the oscillating object 102 is observed, the 3rd resonance mode can be considered to be one of the stable basic modes. In using which [ primary / secondary / 3rd ] resonance mode, it turns out from the result of drawing 4 that the structure of filling 0.2 <=a/l<0.5 or 0.2 <=b/l<0.5 is good.

[0021] Next, in order to compare with this example, the force sensor of other structures is explained. Drawing 5 (a) shows other structures of an oscillating object. The piezoelectric device is joined all over the oscillating object, and the electrode on a piezoelectric device 51 is divided into the excitation electrode 52 and the received electrode 53, and the excitation electrode 52 is used for excitation and, as for the difference with drawing 3 , it uses the received electrode 53 for reception. That is, the propagation section 54 of an oscillating object consists of a piezoelectric device 51 and a monotonous zygote, and it is structure without the difference of the excitation section 55, a receive section 56, and thickness. In this structure, when the frequency characteristics of an output signal were measured, it turned out that it becomes like drawing 5 (b), and peak value is low as compared with drawing 3 , many small peaks appear, and it is hard to produce the resonance mode which can be regarded as a clear basic mode. This example this is indicated to be by drawing 3 is assumed to become easy to produce the knot of vibration near the boundary of the excitation section 103, the propagation section 104 or a receive section 105, and the propagation section 104, for example, for peaks, such as the 3rd resonance, to appear greatly when the thickness of the excitation section 103 and a receive section 105, and the propagation section 104 differs.

[0022] In addition, an excitation electrode and a received electrode are replaced, a receive section can get 103 and the effectiveness same naturally also as the excitation section is acquired in 105.

[0023] (Example 2) The 2nd example of this invention is explained hereafter, referring to a drawing.

[0024] Drawing 1 (a) and drawing 1 (b) are the sectional views and top views of the amount sensor of dynamics in one example of this invention. Since it is the same as that of an example 1, explanation of drawing 1 is omitted.

[0025] In drawing 1 , although the oscillating object 102 is installed in the supporting beam 101 which bends with

migration of an inertial field 100, resonance mode exists also about the whole beam which consists of an inertial field 100 and a supporting beam 101. Although you may think that this resonance mode is the same as that of outline cantilever vibration, an inertial field often moves by the small force, and although, as for the sensibility as a sensor, the one where the deflection of a supporting beam 101 is larger becomes high, the resonance frequency of the whole beam falls so much. The resonance frequency of this whole beam is connected with the frequency range of the force impressed to measure. That is, in the case of the acceleration sensor for automobiles, it is necessary to measure correctly the acceleration of the range of 0-500Hz but, and for example, if the resonance frequency of the whole beam exists in this range, it will become difficult to measure the acceleration near [ this ] the resonance frequency correctly. Therefore, although detection sensitivity becomes high so that it is low, more than a frequency range, for example, designed, to measure is desirable [ the resonance frequency of the whole beam ] 500Hz or more so that it may be ideally set to 1kHz.

[0026] Moreover, mutually-independent [ of the resonance frequency of the whole beam and the resonance frequency of the oscillating object 102 ] is carried out, and they must not influence mutually. In order to explain this, the experimental result of drawing 6 is shown. The axis of ordinate shows the output signal electrical potential difference from a receive section 105 for the frequency of the signal with which an axis of abscissa is impressed to the piezoelectric device of the excitation section 103 of the oscillating object 102. The data of drawing 6 are a thing at the time of l= 5mm, a=b=1.5mm, and h= 1mm in drawing 1 in t1=0.4mm, t2=0.8mm, L1=L2=H=5mm, and drawing 3 . In the curve of drawing 6 , fc0, fc1, and fc2 are the peaks of the resonance frequency of the whole beam, and they are respectively equivalent to the primary resonance frequency [ secondary / 3rd ]. Moreover, fs0, fs1, and fs2 are the resonance frequency of the oscillating object 102, and they are equivalent to the primary resonance mode [ secondary / 3rd ] shown in (c) of drawing 3 , (d), and (e). In drawing 6 , fc0, fc1, and fc2 are in fs0 and the distant enough location. That is, the resonance frequency of the whole beam is in the location left with the resonance frequency of the oscillating object 102, and since it does not influence each other, it can be said that it is the structure where a very good result is obtained. However, fc0 When fs0 is a comparatively near frequency, the case where high order resonance frequency (for example, fc4 grade) laps with fs0 arises on the whole beam, and it becomes impossible to detect the resonance frequency of the oscillating object 102 correctly. Considering that high order resonance mode is contained in resonance of the whole beam, the resonance frequency of the oscillating object 102 to be used and the primary resonance frequency of the whole beam can realize a sensor that it is safe that it is separated from single or more figures, and good.

[0027] In addition, an excitation electrode and a received electrode are replaced, a receive section can get 103 and the effectiveness same naturally also as the excitation section is acquired in 105.

[0028] (Example 3) The 3rd example of this invention is explained hereafter, referring to a drawing.

[0029] Drawing 7 and drawing 8 show the structure of the oscillating object of the 3rd example. Although the structure of the oscillating object shown in drawing 3 was structure which high order resonance of the 3rd resonance etc. tends [ comparatively ] to produce, if it may be able to do, structure which only simple primary resonance frequency produces is desired. Drawing 7 and drawing 8 show the oscillating object structure of filling such a demand. In drawing 7 , an inertial field 100 and a supporting beam 101 are constituted like drawing 1 , the plate 106 on a strip of paper is installed in the top face of a supporting beam 101 in the state of both-ends immobilization, and the piezoelectric device 107 is joined by the upper part. When a plate 106 is an insulator, an electrode is prepared between a piezoelectric device 107 and a plate 106, and when a plate 106 is a conductor, fixed potential can be impressed to the inferior surface of tongue of a piezoelectric device by using a plate 106 as an electrode. On the other hand, the excitation electrode 108 and the received electrode 109 with which the top face of a piezoelectric device was divided into right and left to the line which connects the both ends of a plate 106 are prepared.

[0030] Drawing 8 carries out expansion illustration of the part for the oscillating soma of drawing 7 . When the excitation electrode 108 is continuing and excitation voltage is impressed to an excitation electrode from the fixed end of an oscillating object to the fixed end with such structure, it is the easiest to produce the primary resonance mode shown in drawing 8 (C) by expansion and contraction of the whole oscillating object, and stops producing the resonance mode of the gestalt shrunken by elongation and a certain part by forced oscillation in a part with an oscillating object like the secondary resonance [ 3rd ]. That is, about the sensor of drawing 7 , if the same data as drawing 6 are taken, only resonance frequency fs0 will show a peak clearly, and the peak of fs1 and fs2 will be extinguished.

[0031] Drawing 8 (c) shows the primary resonance mode of a both-ends fixed beam. According to this, since both ends are being fixed, it turns out that the direction where a center section bends, and the direction where the part near an edge bends are hard flow. Therefore, since the charge generated in the center section and the charge generated at the end are opposite signs when vibration of primary resonance mode is used, and the received electrode 109 has the same area in every part of a beam, they offset each other, there are and the fault that output voltage declines as a result arises. So, by this invention, as shown in drawing 8 (a), it is large in the center section, and it narrows at the end, the received electrode 109 is large at the edge, and the excitation electrode 108 consists of the reverse narrowly in the center section. Thus, by constituting, the opposite sign component of the charge generated in a received electrode decreases, receiving sensibility rises, it can be sharp and the peak in primary resonance frequency can be made high.

[0032] In addition, an excitation electrode and a received electrode are replaced, a received electrode can obtain 108 and the effectiveness same naturally also as an excitation electrode is acquired in 109.

[Translation done.]

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]
[Drawing 1] The sectional view and top view of a force sensor in the 1st example of this invention
[Drawing 2] The acceleration-frequency-characteristics Fig. showing the example of measurement of the acceleration in the 1st example of this invention
[Drawing 3] The schematic diagram showing the enlarged drawing of the oscillating soma in the 1st example of this invention, and the various oscillation modes
[Drawing 4] The graph which shows the frequency characteristics in the 1st example of this invention
[Drawing 5] The block diagram of the force sensor of other configurations for the comparison to the 1st example of this invention
[Drawing 6] The frequency-characteristics Fig. in the 2nd example of this invention
[Drawing 7] The sectional view and top view of a force sensor in the 3rd example of this invention
[Drawing 8] The oscillating soma enlarged drawing in the 3rd example of this invention, and the schematic diagram of the oscillation mode
[Drawing 9] The perspective view of the conventional force sensor
[Drawing 10] The perspective view of the conventional force sensor
[Description of Notations]
100 Inertial Field
101 Supporting Beam
102 Oscillating Object
103 Excitation Section
104 Propagation Section
105 Receive Section
107 Piezoelectric Device
108 109 Electrode

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[Translation done.]

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DRAWINGS

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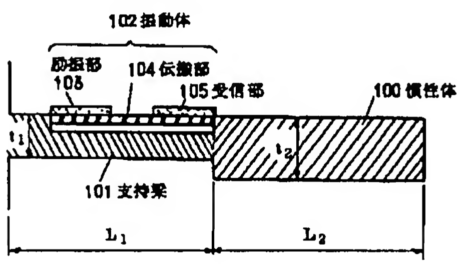
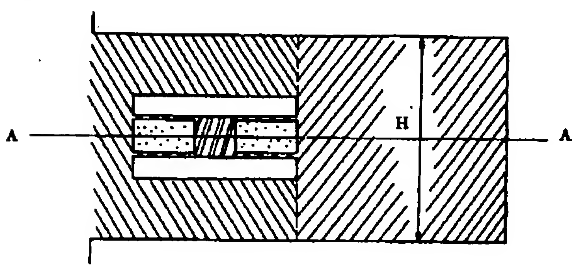
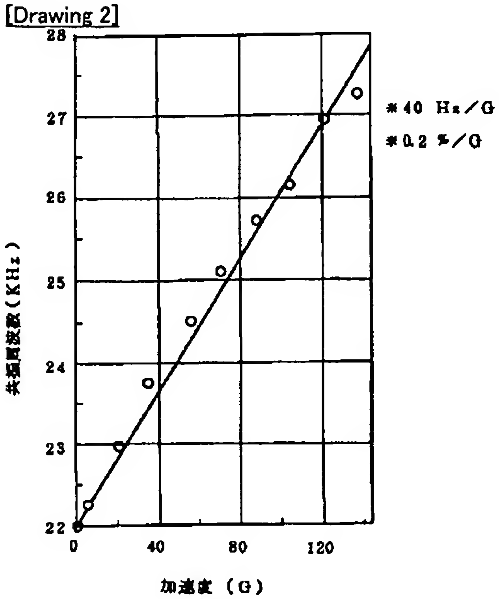
[Drawing 1]
(a)



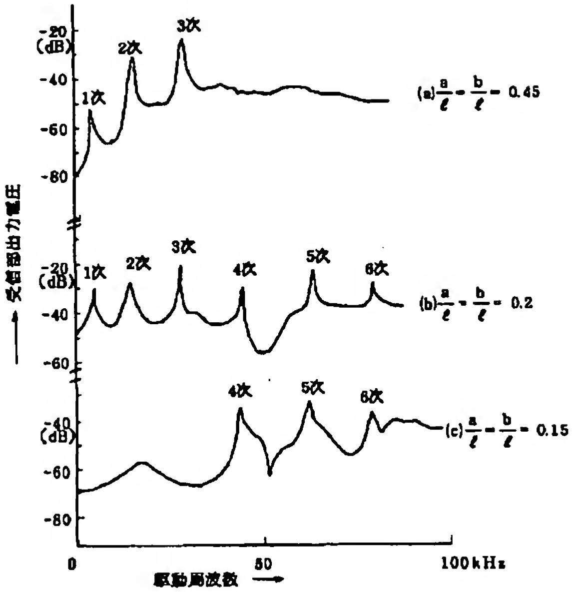

(b)



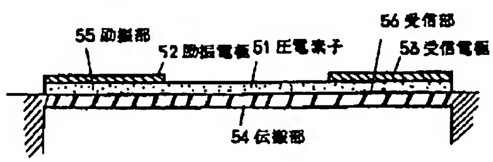

[Drawing 2]




[Drawing 4]




[Drawing 5]
(a)

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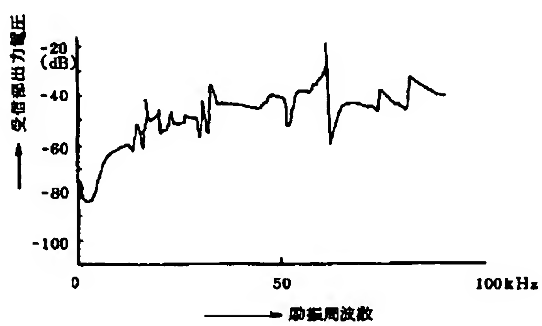
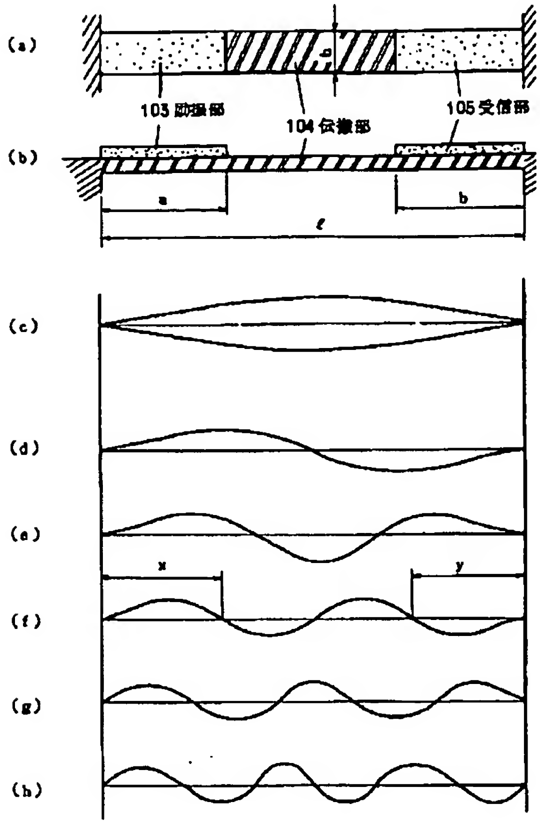
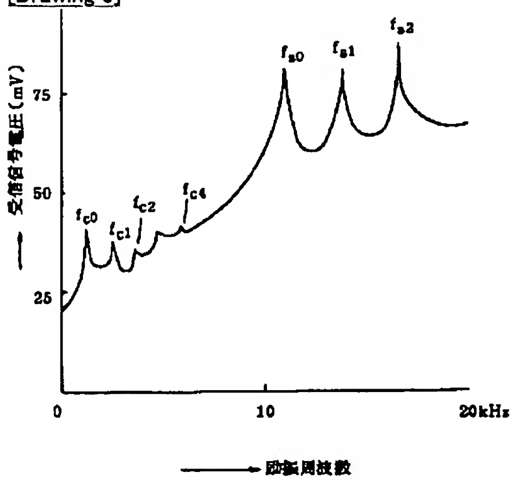



[Drawing 3]

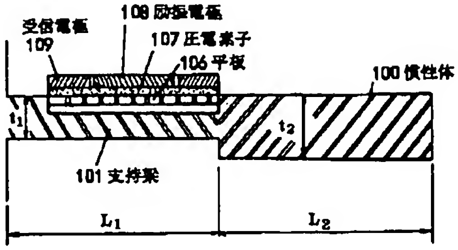



[Drawing 6]




[Drawing 7]

(a)

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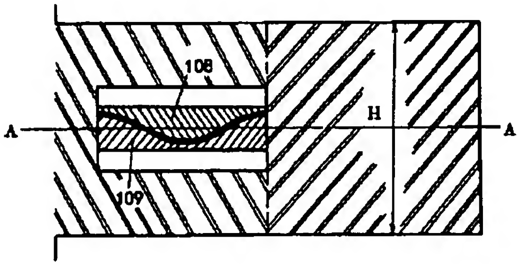
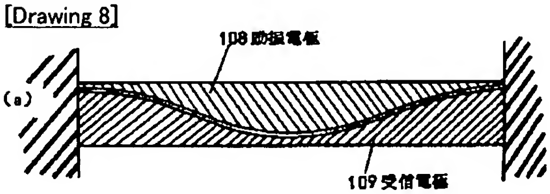



[Drawing 8]

(a)

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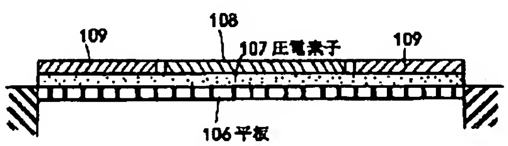
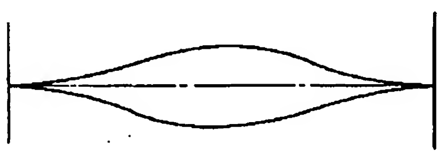
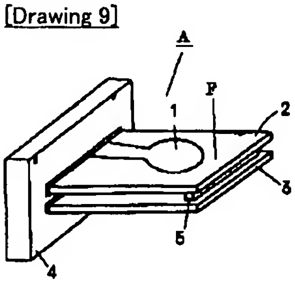


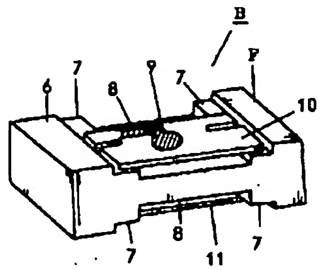

(c)



[Drawing 9]




[Drawing 10]




[Translation done.]

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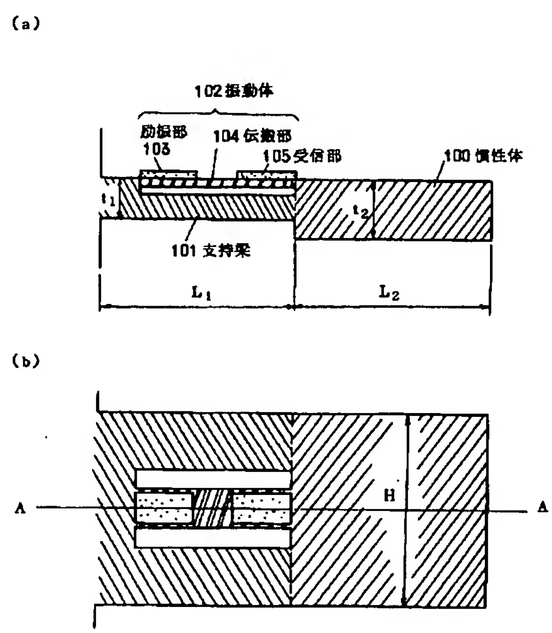
最終頁に続く

(54)【発明の名称】力センサー

(57)【要約】

【目的】　力を検出するセンサーに関するもので、従来の圧電共振型センサーの不要な共振モードが現れるという欠点を解決し、使用する共振周波数のピークを鋭く、高くし、誤動作がなく安定な力センサーの実現を目的とする。

【構成】　加速度により移動可能な慣性体と、それを支持する支持梁と、支持梁上に設置された振動体を備え、振動体は振動体を励振する励振部と振動を伝搬する伝搬部と、振動状態を受信する受振部とよりなり、力が印加された際、振動体の変形により生じる振動状態の変化を、励振部への入力信号と受信部の出力信号により検出し、力を測定するものであり、励振部、受信部に圧電素子を用い、励振部及び受信部の長さを振動体の全長の０．２～０．５倍に構成することにより、振動体の低次共振周波数のピークが明確に現れ、常に一定の共振モードを容易に保てるようになり、誤動作のない安定な力センサーが実現できる。



【特許請求の範囲】

【請求項１】　力学量の作用により移動可能な慣性体と、慣性体を支持する支持梁と、前記支持梁上に設けられて両端を前記支持梁に固定された振動体と、前記振動体の一端部付近に接合されて前記振動体を励振する励振用圧電素子と、前記振動体の他端部付近に接合されて前記振動体の振動を受信する受信用圧電素子とを具備し、前記振動体の全長ｌと、前記励振用圧電素子の長さａ及び前記受信用圧電素子の長さｂとの間には、

０．２　≦　ａ／ｌ　＜　０．５

又は

０．２　≦　ｂ／ｌ　＜　０．５

の関係があることを特徴とする力センサー。

【請求項２】　力学量の作用により移動可能な慣性体と、慣性体を支持する支持梁と、前記支持梁上に設けられて両端を前記支持梁に固定された振動体とを具備し、前記振動体の１次共振周波数が、前記慣性体と前記支持梁の１次共振周波数の１０倍以上であることを特徴とする力センサー。

【請求項３】　力学量の作用により移動可能な慣性体と、慣性体を支持する支持梁と、前記支持梁上に設けられて両端を前記支持梁に固定された振動体と、前記振動体上に接合された圧電素子と、前記圧電素子の表面上に前記振動体の長手方向と交差する方向に分割された一対の電極とを具備し、前記一対の電極の一方は振動体を励振する励振用電極、他方は振動体の振動を受信する受信用電極であることを特徴とする力センサー。

【請求項４】　圧電素子上に分割して設けられた一対の電極が、一方は振動体の中央部で広く固定端近傍で狭い形状であり、他方は振動体の中央部で狭く固定端近傍で広い形状であることを特徴とする請求項３記載の力センサー。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、物体に印加される加速度、加重、圧力等の力学量を検出するセンサーに関するものである。

【０００２】

【従来の技術】近年、自動車事故での安全を守るエアバックシステムや、道路案内を行うナビゲーションシステムなどの開発が盛んであり、それに伴い加速度センサーや振動ジャイロのようなセンサーが開発されている。

【０００３】従来力検出素子としては、例えば特公昭５３－１３３０号公報に示されているように、図９あるいは図１０の構造が知られている。図９において、それぞれ電極１が取り付けられている２枚の圧電振動板２、３を一定の空隙を介在させて配置し、これら圧電振動板２、３の各一端を基板４に固定すると共に同他端を間隔板５により剛性的に結合してなるもので、圧電振動板２、３の自由端に力Ｆが加えられた時に、このとき圧電振動板２、３が受ける変位に基づくこれら圧電振動板２、３の各固有振動数の変化を測定し、この結果に基づいて前記力Ｆを測定するようにしたものである。また図１０はカンチレバー６の上下面に段部７、溝８を形成し、溝８を架橋して電極９の取り付けられている２枚の圧電振動板１０、１１を固定してなるもので、カンチレバー６の自由端に力Ｆが印加されたとき圧電振動板１０、１１の各固有振動数の変化の差を検出して力Ｆを測定するようにしたものである。



【０００４】

【発明が解決しようとする課題】しかしながら上記の従来の構成の圧電振動板２、３、１０、１１では、種々のモードの固有振動が生じる。すなわち、縦方向、横方向の振動モードおよびその高次共振、梁全体の固有振動モード、捻れ振動などが存在し、それらを明確に区別分離して、使用したい固有振動モードのみを他と区別して取り出し安定して共振状態を保つことが困難であった。

【０００５】本発明は上記従来技術の課題を解決するもので、力の印加により、固有振動数の変化する振動体の固有振動モードが、他の不要な共振モードと完全に分離でき常に一定の共振状態を安定に保てる、力学量センサーを提供することを目的とする。

【０００６】

【課題を解決するための手段】この目的を達成するために本発明は、第１に力学量の作用により移動可能な慣性体と、慣性体を支持する支持梁と、前記支持梁上に設けられて両端を前記支持梁に固定された振動体と、前記振動体の一端部付近に接合されて前記振動体を励振する励振用圧電素子と、前記振動体の他端部付近に接合されて前記振動体の振動を受信する受信用圧電素子とを具備し、前記振動体の全長ｌと、前記励振用圧電素子の長さａ及び前記受信用圧電素子の長さｂとの間には、

０．２　≦　ａ／ｌ　＜　０．５

又は

０．２　≦　ｂ／ｌ　＜　０．５

の関係があることを特徴とするものである。また第２に、力学量の作用により移動可能な慣性体と、慣性体を支持する支持梁と、前記支持梁上に設けられて両端を前記支持梁に固定された振動体とを具備し、前記振動体の１次共振周波数が、前記慣性体と前記支持梁の１次共振周波数の１０倍以上であることを特徴とするものである。さらに第３に、力学量の作用により移動可能な慣性体と、慣性体を支持する支持梁と、前記支持梁上に設けられて両端を前記支持梁に固定された振動体と、前記振動体上に接合された圧電素子と、前記圧電素子の表面上に前記振動体の長手方向と交差する方向に分割された一対の電極とを具備し、前記一対の電極の一方は振動体を励振する励振用電極、他方は振動体の振動を受信する受信用電極であることを特徴とするものである。

【０００７】

【作用】本発明は上記構成によって、第1に、高次モードの共振のピークを低下あるいは消滅させ、振動体の低次モードの共振周波数が明確にピークを示し、安定した共振モードでの駆動が可能となる。また第2に、振動体の1次共振周波数が、慣性体と支持梁の1次共振周波数の10倍以上としたものであり、梁全体の共振周波数の影響を受けることなく、振動体を安定して共振させることができる。さらに第3に、振動体の1次共振周波数のみを生じさせることができるので、常に同一モードの1次共振における安定した駆動が可能であり、誤動作の少ないセンサーが実現できる。

【0008】

【実施例】

（実施例1）以下、本発明の第1の実施例について、図面を参照しながら説明する。

【0009】図1（a）、図1（b）は本発明の一実施例における力学量センサーの断面図および平面図である。図1（a）において、100は慣性体、101は支持梁、102は振動体であり、前記振動体102は励振部103、伝搬部104、受信部105より構成されている。

【0010】図1において、加速度が印加されると慣性体100が上下し、支持梁101がたわむと共に振動体102は伸び縮みする。そのため、力が作用した際には、振動体の共振周波数が変化することになり、この周波数変化を検出することにより加速度を測定することができる。例えば、振動体の振動が糸の振動と仮定できるとすると、共振周波数fは（数1）で表される。

【0011】

【数1】

$$f = \frac{n}{2l} \cdot \sqrt{\frac{S}{\rho}}$$

【0012】但しlは糸の長さ、Sは糸の張力、ρは糸の単位長さ当りの質量、nは振動の次数を示す。（数1）によれば、共振周波数fは糸の張力の平方根に比例して変化し、力が作用した際に、振動体の張力が変化する構造であれば加速度、圧力、力等の力学量が測定できることが分かる。

【0013】図2は図1の構成に於ける特性例である。縦軸は振動体の共振周波数fであり、横軸は印加された加速度を示す。これによると、加速度0のときの共振周波数は22kHzであるが、120Gの加速度が印加された場合には27kHzに上昇する。1Gあたり約40Hzの変化があり、変化率で言うと0．2%／Gで且つ図にみられるように非常に大きな加速度まで測定でき、ダイナミックレンジの広い加速度センサーが実現できた。なお、図1の構造では、慣性体の質量と支持梁部の質量の比により感度が異なるが、図2のデータの場合慣性体が支持梁部の7倍の構造のものであり、比較的微小な支持梁のたわみが、振動体への大きな張力となって作用し、大きな感度を出力することができたと考えられる。

【0014】本実施例の構造的な特徴の1つは、振動体の構造であり、励振部、伝搬部、受信部により構成されている点である。一般に、圧電セラミックを共振させた場合、圧電セラミック自体の厚み振動等の場合には、圧電セラミック自体のインピーダンス変化を検出して共振点を知る方法がある。しかしながら、本発明のように、振動体が圧電セラミックと他の構造部材との接合体の場合には、接合体の共振周波数において、必ずしも大きなインピーダンス変化があるとは限らず、感度良く共振点を検出できない場合が多い。それに比較して、本発明では前記接合体である振動体の振動を直接受信部で検出しているため、振動体の持つあらゆる振動を正確に検出することが可能となり、適切な振動体構造の設計において、寸法的な自由度が非常に大きなものとなる。

【0015】図3は、図1の振動体102の振動状態を説明するためのものである。図3（a）、（b）は振動体102の部分を拡大図示した平面図および断面図である。振動体102は両端に圧電素子が設けられており、左端に励振部103、右端に受信部105が構成されている。このような振動体は一般に、図3（c）～（h）に示されているように種々の振動モードで共振し、各々1次～6次共振モードと呼ばれている。これらの共振モードが生じる、振動周波数は、振動体の厚みと長さそして振動体を構成する材質のヤング率などによって一義的に決定され振動体の幅hには依存しない。

【0016】上記のような、共振モードの起き易さは、励振部103の長さaと密接な関係がある、振動体は励振部103の圧電素子の伸縮振動によって振動を起こし、励振の周波数が共振モードの生じる周波数と一致したとき、共振モードでの振動が生じることになる。ここで、励振部の長さaと生じ易い振動モードの関係を考えるため、例として図3（f）の4次共振モードでの節と節間の長さをxとする。励振部は圧電素子の伸縮により変形するので励振部の自然な変形状態は励振部103の両端を節とする弓状と考えられる。従ってaとxがほぼ等しい状態となるような共振モードは生じ易いと考えられ、例えばxがaの半分程度になると、励振部の圧電素子は伸びる部分と縮む部分の両方が生じることになり、このような振動モードを強制振動により生じさせるのは非常に困難なものとなる。

【0017】同様に、受信部105の長さbと図3（f）における長さyについても、同様なことが言え、b≒yのときには受信部104の圧電素子が全面で同一方向の歪を受けるため充分な出力信号が得られるが、yがbに比較して小さくなると受信部104の圧電素子には逆の歪が生じる部分ができるようになり、ある部分では正の電荷がまた他の部分では負の電荷が生じる状態と

なり、出力信号が低下することになる。

【００１８】図４は、励振部１０３、受信部１０５の寸法を変化させたときの、受信部１０５から出力される出力信号の周波数特性を示す実験結果である。横軸は励振部１０３の圧電素子に印加される正弦波形の入力信号の周波数を示しており、縦軸はそのときの受信部の圧電素子からの出力電圧を示している。例えば、励振部１０３に数Ｖの信号電圧を印加すると、受信部からは数ｍＶから数百ｍＶの出力電圧が得られるが、その値は、共振周波数で急激に大きくなるため、図４のように横軸に周波数をとると共振周波数でピークを有する曲線が得られる。ここで、振動体１０２は４－２アロイに圧電素子（住友金属性Ｈ５Ｄ）を接着させて作製し、４－２アロイ及び圧電素子の厚みは８０μｍとした。図３において、ｈ＝２ｍｍ、ｌ＝１０ｍｍとし、励振部１０３および受信部１０５の寸法ａ、ｂは等しい値として、ａ、ｂを変化させた。

【００１９】図４、（ａ）はａ、ｂが比較的大きく、ａ／ｌ＝０．４５のときの周波数特性を示すが、１次、２次、３次の共振モードでのピークがみられ、それ以上の４次、５次共振のピークはみられない。これらの高次の共振モードは、ａ、ｂが小さくなるにしたがって現れ、例えば図４（ｂ）のようにａ／ｌ＝０．２では、６次共振モードまで生じてくる。さらに、図４（ｃ）はａ／ｌ＝０．１５とａ、ｂをさらに小さくした場合であるが、あまりａ、ｂが小さすぎると、１次、２次、３次の低次の共振モードが消え、高次の共振モードのみ現れることが分かった。

【００２０】一般に、高次の共振モードより低次の共振モードの方が安定であると言われている。これは、図３のような形状の振動体の場合に、図３（ｃ）～（ｈ）で示された振動モードの他に、幅方向（ｈ）の共振や捻れ振動の共振モードがあり、これらは、高次共振モードの周波数近辺に現れ易く、周波数特性でいうと、高次共振モードのピークの近傍に、他のモードのピークが生じ、回路上、高次共振モードのピーク点の周波数で常時駆動させる方法が難しくなるというようなことが理由である。従って、本発明の構成に於いても、低次の共振モードを使用するのが良く、１次、２次、３次共振モードのうちのいづれかを選択するのが安全である。このうち３次共振モードは、振動体１０２の伝搬部１０４のみに注目した場合、この３次共振モードが伝搬部１０４の１次共振モードに相当するので、安定な基本モードの１つと考えることができる。１次、２次、３次のいづれかの共振モードを使用する場合には、図４の結果から、０．２≦ａ／ｌ＜０．５あるいは０．２≦ｂ／ｌ＜０．５を満たす構造が良いことが分かる。

【００２１】次に本実施例と比較するために他の構造の力センサーについて説明する。図５（ａ）は、振動体の他の構造を示す。図３との相違点は、圧電素子が振動体全面に接合されており、圧電素子５１上の電極が、励振電極５２と受信電極５３に分割されており、励振電極５２を励振用に、受信電極５３を受信用に使用するものである。すなわち、振動体の伝搬部５４が圧電素子５１と平板の接合体で構成されており、励振部５５や受信部５６と厚みの差がない構造である。この構造において、出力信号の周波数特性を測定したところ、図５（ｂ）のようになり、図３と比較してピーク値が低く、小さなピークがたくさん現れ、明快な基本モードと思える共振モードを生じさせにくいことが分かった。これは、図３で示される本実施例は励振部１０３及び受信部１０５と伝搬部１０４の厚みが異なることによって、励振部１０３と伝搬部１０４あるいは受信部１０５と伝搬部１０４の境界付近に振動の節が生じ易くなり、例えば３次共振等のピークが大きく現れるためと想定される。

【００２２】なお、励振電極と受信電極を入れ替え、１０３を受信部、１０５を励振部としても当然同様な効果が得られる。

【００２３】（実施例２）以下、本発明の第２の実施例について、図面を参照しながら説明する。

【００２４】図１（ａ）、図１（ｂ）は本発明の一実施例における力学量センサーの断面図および平面図である。図１の説明は実施例１と同様なので省略する。

【００２５】図１において、振動体１０２は、慣性体１００の移動にともなってたわむ支持梁１０１に設置されているが、慣性体１００と支持梁１０１よりなる梁全体についても、共振モードが存在する。この共振モードは概略片持梁の振動と同様と考えて良いが、小さな力で慣性体がよく動き、支持梁１０１のたわみが大きい方が、センサーとしての感度は高くなるが、それだけ、梁全体の共振周波数は低下する。この梁全体の共振周波数は、測定したい印加される力の周波数範囲と関連する。すなわち、例えば、自動車用の加速度センサーの場合には、０～５００Ｈｚの範囲の加速度を正確に測定する必要があるが、この範囲に梁全体の共振周波数が存在すると、この共振周波数近傍の加速度を正確に測定することが困難になる。したがって、梁全体の共振周波数は、低いほど検出感度が高くなるけれども、測定したい周波数範囲以上、例えば、５００Ｈｚ以上、理想的には１ｋＨｚとなるよう、設計されることが望ましい。

【００２６】また、梁全体の共振周波数と、振動体１０２の共振周波数は互いに独立しており、互いに影響してはならない。このことを説明するために、図６の実験結果を示す。横軸は振動体１０２の励振部１０３の圧電素子に印加される信号の周波数を、縦軸は受信部１０５からの出力信号電圧を示している。図６のデータは、図１において、ｔ１＝０．４ｍｍ、ｔ２＝０．８ｍｍ、Ｌ１＝Ｌ２＝Ｈ＝５ｍｍ、図３においてｌ＝５ｍｍ、ａ＝ｂ＝１．５ｍｍ、ｈ＝１ｍｍの時のものである。図６の曲線に於いて、ｆｃ０，ｆｃ１，ｆｃ２は梁全体の共振周

波数のピークであり、各々１次、２次、３次共振周波数に相当する。また、ｆｓ０、ｆｓ１、ｆｓ２は、振動体１０２の共振周波数であり、図３の（ｃ）、（ｄ）、（ｅ）に示された、１次、２次、３次共振モードに相当する。図６において、ｆｃ０、ｆｃ１、ｆｃ２はｆｓ０と充分離れた位置にある。すなわち、梁全体の共振周波数は振動体１０２の共振周波数と離れた位置にあり、互いに影響し合うことないので非常に良好な結果が得られる構造であると言える。しかし、ｆｃ０、と　ｆｓ０が比較的近い周波数であった場合には、梁全体に高次の共振周波数（例えばｆｃ４等）がｆｓ０と重なる場合が生じ、振動体１０２の共振周波数を正確に検出することができなくなる。梁全体の共振には、高次の共振モードが含まれることを考えると、使用する振動体１０２の共振周波数と、梁全体の１次共振周波数は一桁以上離れているのが安全で良好なセンサーを実現できる。

【００２７】なお、励振電極と受信電極を入れ替え、１０３を受信部、１０５を励振部としても当然同様な効果が得られる。

【００２８】（実施例３）以下、本発明の第３の実施例について、図面を参照しながら説明する。

【００２９】図７、図８は、第３の実施例の振動体の構造を示す。図３に示された振動体の構造は３次共振などの高次共振が比較的生じ易い構造であったが、でき得れば、単純な１次共振周波数のみが生じるような構造が望まれる。図７、図８はそのような要求を満たす振動体構造を示している。図７において、慣性体１００および支持梁１０１は図１と同様に構成され、支持梁１０１の上面に両端固定の状態で短冊上の平板１０６が設置され、その上部に圧電素子１０７が接合されている。平板１０６が絶縁体の場合は圧電素子１０７と平板１０６の間に電極を設け、平板１０６が導電体の場合は平板１０６を電極として、圧電素子の下面に一定電位が印加できるようになっている。一方、圧電素子の上面は平板１０６の両端を結ぶ線に対して左右に分割された、励振電極１０８と受信電極１０９が設けられている。

【００３０】図８は、図７の振動体部分を拡大図示したものである。このような構造では、振動体の固定端から固定端まで、励振電極１０８が連続しており、励振電極に励振電圧を印加した際、振動体全体の伸び縮みによる図８（Ｃ）に示した１次共振モードが一番生じ易く、２次、３次共振のような振動体のある部分では伸び、ある部分では縮む形態の共振モードは、強制振動によって生じなくなる。すなわち、図７のセンサーについて、図６と同様なデータをとると、共振周波数ｆｓ０のみが明確にピークを示し、ｆｓ１，ｆｓ２のピークが消滅する。

【００３１】図８（ｃ）は両端固定梁の１次共振モードを示している。これによると、両端が固定されているため、中央部のたわむ方向と端部に近い部分のたわむ方向が逆方向になっていることがわかる。したがって、１次



共振モードの振動を使用した場合、受信電極１０９が梁のどの部分でも同様な面積を有していた場合には、中央部で発生する電荷と端部で発生する電荷が異符号であるため、それらが相殺しあって、結果として出力電圧が低下するという欠点が生じる。そこで本発明では、図８（ａ）に示すように励振電極１０８を中央部で広く、端部で狭くし、受信電極１０９はその逆で端部で広く、中央部で狭く構成している。このように構成することによって受信電極に発生する電荷の異符号成分が減少し、受信感度が上昇し、１次共振周波数でのピークを鋭く、高いものとすることができる。

【００３２】なお、励振電極と受信電極を入れ替え、１０８を受信電極、１０９を励振電極としても当然同様な効果が得られる。

【００３３】

【発明の効果】以上のように本発明は、第１に、振動体の全長ｌと、前記励振用圧電素子の長さａ及び前記受信用圧電素子の長さｂとの間に、

$$0.2 \leq a/l < 0.5$$

又は

$$0.2 \leq b/l < 0.5$$

の関係を有する構成にすることにより、高次モードの共振のピークを低下あるいは消滅させ、振動体の低次モードの共振周波数が明確にピークを示し、安定した共振モードでの駆動が可能となる優れた力センサーを実現できるものである。

【００３４】また第２に、振動体の１次共振周波数が、慣性体と支持梁の１次共振周波数の１０倍以上とした構成により、梁全体の共振周波数の影響を受けることなく、振動体を安定して共振させることができる優れた力センサーを実現できるものである。

【００３５】さらに第３に、圧電素子の表面上に振動体の長手方向と交差する方向で分割された一対の電極を設けた構成により、振動体の１次共振周波数のみを生じさせることができるので、常に同一モードの１次共振における安定した駆動が可能であり、誤動作の少ない優れた力センサーを実現できるものである。

【図面の簡単な説明】

【図１】本発明の第１の実施例における力センサーの断面図及び平面図

【図２】本発明の第１の実施例における加速度の測定例を示す、加速度ー周波数特性図

【図３】本発明の第１の実施例における振動体部の拡大図と種々の振動モードを示す概略図

【図４】本発明の第１の実施例における周波数特性を示すグラフ

【図５】本発明の第１の実施例に対する比較のための他の構成の力センサーの構成図

【図６】本発明の第２の実施例における、周波数特性図

【図７】本発明の第３の実施例における、力センサーの

断面図及び平面図

【図８】本発明の第３の実施例における、振動体部拡大図、及び振動モードの概略図

【図９】従来の力センサーの斜視図

【図１０】従来の力センサーの斜視図

【符号の説明】

１００　慣性体

１０１　支持梁

１０２　振動体

１０３　励振部

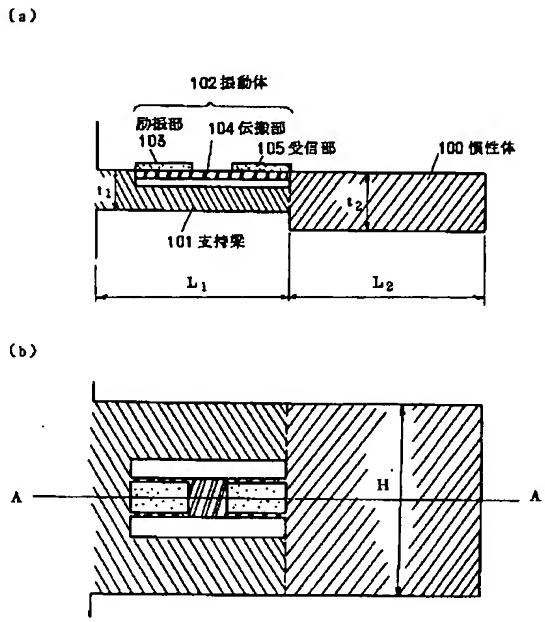
１０４　伝搬部

１０５　受信部

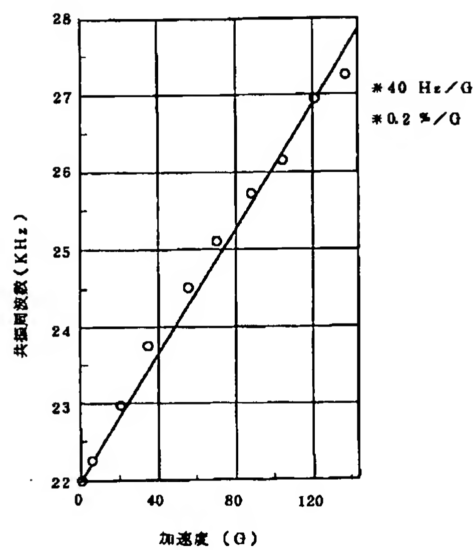
１０７　圧電素子

１０８、１０９　電極

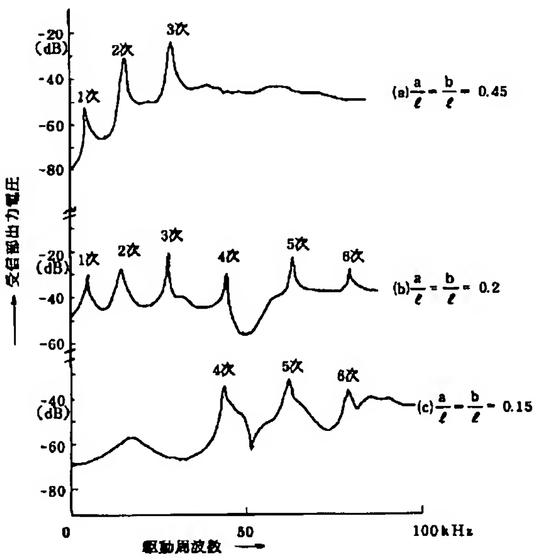
【図１】



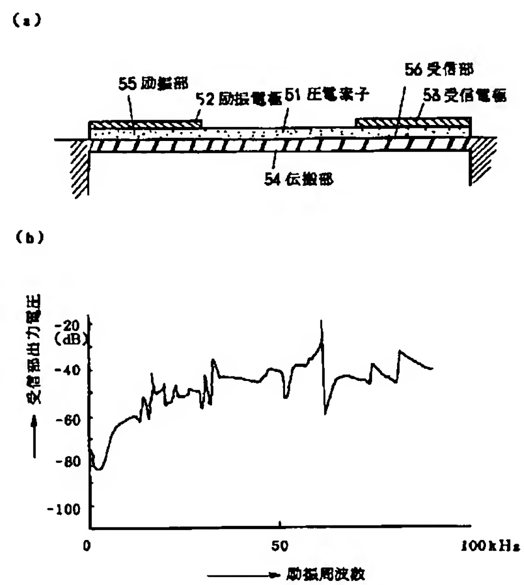

【図２】



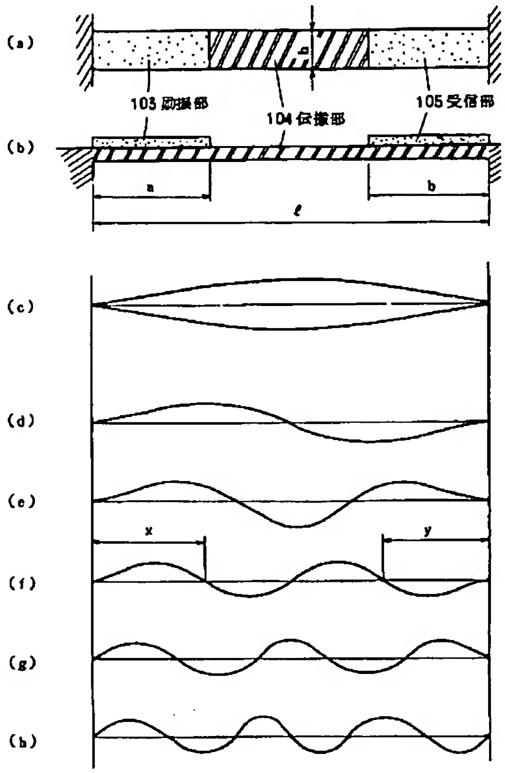

【図４】



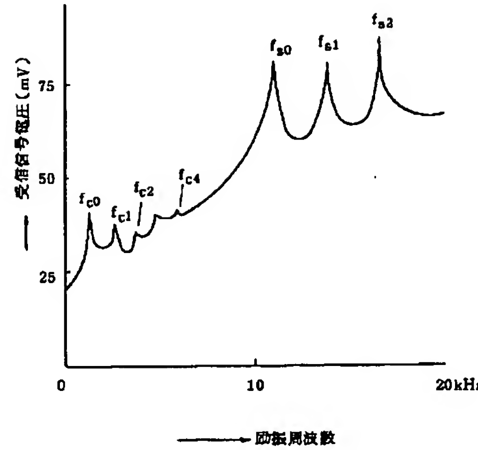

【図５】



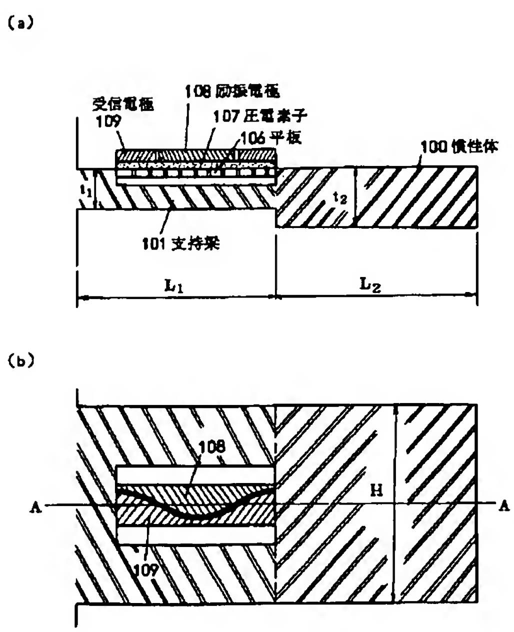
【図３】



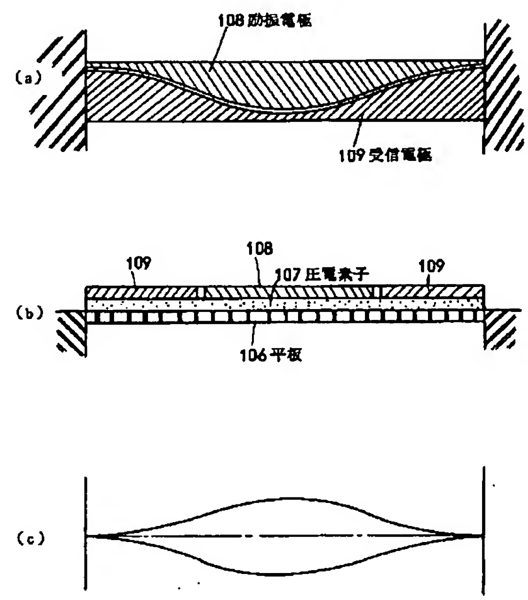

【図６】



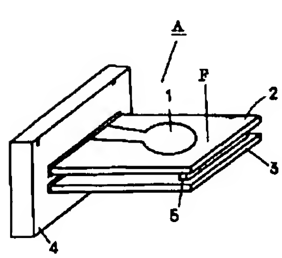

【図７】



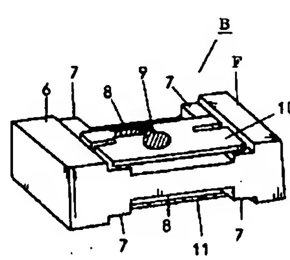

【図８】




【図９】




【図１０】



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